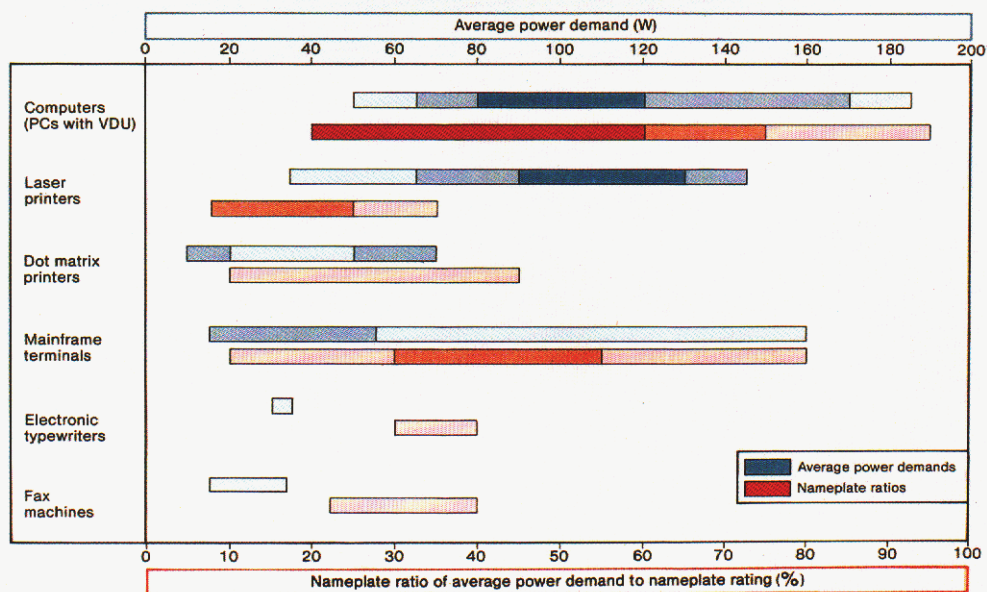


Economic Use of Electricity in Buildings



Energy Efficiency Office
DEPARTMENT OF THE ENVIRONMENT

BEST PRACTICE PROGRAMME

Economic Use of Electricity in Buildings

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Cover: Small power loads in offices

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1. Introduction

Nearly 34% of the UK inland primary energy consumption goes to generating electricity.

Electricity is extremely flexible in the ways it can be used. It can provide amongst other things: lighting, heating, and refrigeration in the domestic sector; air conditioning and lifts in commercial buildings and hotels; and many industrial processes from metal melting to driving rotating machinery.

The proper utilisation of electricity supply has to be set against an economic background. This booklet gives guidance on terms used in electricity tariffs and how plant can be operated with a view to reducing costs. It also explains how the efficient operation and maintenance of electrically powered plant and its correct loading are essential in the search for economic use of electricity and outlines how this may be achieved.

Later in this booklet it will be shown how tariffs are constructed so that consumers are encouraged to operate in the most economical way, and it will be useful to see what practical measures can be taken to further these ends and save money.

2. Cost saving methodology

Energy savings fall into three broad categories. The first category can loosely be described as elimination of 'excess'. Examples of this are when buildings are overheated, lights and machines left on needlessly and doors are left open. These excesses can frequently be significantly reduced by the implementation of a 'good housekeeping' policy and generally require little, if any, technical competence.

The second category, following the identification and elimination of excesses, is the maintenance of the desired conditions. This can be done either by continuous human monitoring or by the use of monitoring and control equipment. This equipment can be provided with varying degrees of capability and will be discussed in detail later in this booklet. Furthermore, having brought operating conditions to a satisfactory level, the efficient operation of electrical equipment itself should be examined with a view to improvement.

The third category is to look to new methods or changes to equipment to achieve the desired

results with preferably a lower energy cost. In addition, though not considered here, improvements to building fabric are another route to energy saving (see Fuel Efficiency Booklet No 16 - 'Economic thickness of insulation for existing industrial buildings' - for further information).

In each of the second and third above mentioned categories there will be a need for technical competence and advice. Identification and implementation of all three categories of savings may be aided by an effective system of Monitoring and Targeting (M&T). This is discussed later in this booklet.

It will be seen that the three categories discussed would appear to be in order of investment cost to produce the desired effect. Hence good housekeeping should involve little, if any, capital cost, but at the other end of the spectrum, plant renewal may require considerable investment. It therefore follows that good housekeeping is almost certainly an area that will produce profitable results.

2.1 Good housekeeping

Much has already been written about good housekeeping and actions such as switching off unwanted electric lights and machines. It is not proposed to do any more in this booklet than to re-emphasise the importance of this area of cost saving.

2.2 Economic operation

In reviewing the economic operation of electrical plant, consideration must be given to the pattern of consumption as well as the level of consumption. In order to reduce costs the following topics will be examined:

- Maintenance
- Electricity supply costs and tariffs
- Meters and meter reading
- Power factor and its correction
- Load Management
- Motors and drives
- Lighting
- Refrigeration
- Monitoring and Targeting

3. Maintenance

In general terms maintenance can be considered in two categories: 'Emergency' and 'Planned'.

3.1 Emergency maintenance

This can hardly be regarded as maintenance in the sense that, in most cases, it consists of a hurried repair to, or replacement of, some unit that has ceased to function effectively. Obviously it is better to follow a rigorous 'Planned Maintenance Programme' to reduce the frequency of emergency maintenance tasks.

3.2 Planned maintenance

In the use of electrical plant and equipment there are obviously sources of danger which are recognised in the 1989 Electricity at Work Regulations. These Regulations are mandatory and serve to ensure that all electrical plant and equipment is adequately maintained and tested to prevent any dangerous situation arising that could harm the users of such equipment. Normally, maintenance carried out solely for safety reasons will be covered by standard procedures, which in some instances will have to satisfy the relevant British Standard Codes of Practice. For example, BS 6867:1987 covers 'The maintenance of electrical switchgear for voltages of up to and including 145 kV' (High Voltage) and BS 6423:1983 'Maintenance of electrical switchgear and control gear for voltages up to and including 650 V' (Low Voltage). As this type of maintenance is not normally discretionary it is not proposed to bring it into discussions on economic considerations.

Other maintenance, although not mandatory, is regarded as extremely desirable to secure the most practical and economic operation of the plant and equipment.

Planned maintenance can be carried out on the basis of the operation of the piece of electrical equipment itself. For example, it is worth considering whether all electric motors should be periodically cleaned and inspected, making sure that dirt and dust has not interfered with the self cooling of the motor and that there is no oil leakage into the motor's windings. Bearings should also be checked for wear to prevent

contact between the rotor and stator, which would give rise to a build up of additional mechanical losses and hence reduced efficiency of operation.

Maintenance can also be based more on the complete item of plant, or auxiliary plant; for example, a particular production line or air conditioning unit.

3.3 Purposes of maintenance

Apart from safety, maintenance is needed to keep plant in an acceptable condition. Maintenance of this kind must be reviewed on an economic basis. Whilst it is appreciated that breakdown of plant may result in costly loss of production it must also be borne in mind that stopping plant to maintain it can also cause a loss in production. Equipment on continuous and arduous duty will in most circumstances require more attention than that which is lightly loaded and rarely used.

3.4 Economics of maintenance

Apart from the above considerations there will be the question of whether to repair or replace. This entails being able to analyse past and future maintenance costs and the benefits of new equipment. There has been much operational research carried out into such things as the probability of breakdown, replacement and repair limits, and overhaul policies. This obviously requires considerable effort and expertise and may need the services of an outside consultant; however, some simple first steps can be taken.

3.4.1 Standardisation of equipment

The use as far as possible of standard items such as switchgear will help both in buying, stockholding and replacement of components on the most economical and the most convenient basis.

3.4.2 Establishment of records on breakdowns

Initially this may be on a simple log book or card system. This information should give some idea of which plant requires attention and at what intervals. It may also lead to improvements in methods of operation or to modifications to the plant itself which will reduce the frequency of future failures.

3.4.3 *Frequency of maintenance*

This needs careful organisation to ensure that it fits in with operational requirements. All planned maintenance programmes should therefore have been agreed with the operation's controller prior to implementation.

3.4.4 *Economics of routine maintenance*

It may not be economical or practicable to include some equipment in a scheduled routine although safety inspections will still need to be carried out. Examples of low priority non-safety maintenance are:

- Equipment that is not subject to frequent breakdown e.g. electric heaters
- Equipment that would cause little or no interference with operational routines and could be repaired or replaced to fit in with the other demands on the maintenance department.

In some cases it may be found that as little as 25% of the plant needs to be maintained on a scheduled routine throughout the year. Whilst the setting up of a successful maintenance operation is not an easy task, the economic advantages can be considerable.

The use of a PC-supported database may assist in both setting up a record system and scheduling maintenance programmes. Bear in mind that each establishment has its own particular problems and financial guidelines, and any programme must be tailored to suit the operational and economic parameters of the organisation.

3.4.5 *Upgrading to more efficient plant*

Energy savings can be achieved by changing the type of equipment in use, for example:

- changing from low efficiency lighting such as tungsten filament lamps;
- replacing electro-mechanical environmental controls with electronic systems;
- installing modern high efficiency motors to replace old low efficiency electric motors particularly where extended duty operations prevail;

- retrofitting variable speed drives for flow control of fans or pumps.

The economics of changing inefficient existing systems, which are continuing to provide a satisfactory operational performance, obviously requires careful consideration. Not only do costs in use need to be understood, but also equipment life can have a significant impact on the overall financial viability of any proposed changes.

4. **Electricity supply costs and tariffs**

With electricity satisfying many varied uses, and coupled with the relative ease of metering this usage, the Electricity Supply Industry has devised a range of tariffs which have been tailored to reflect different consumers' consumption patterns. Not only are these tariffs tailored for specific users such as domestic, commercial, agricultural and industrial, but they are also sub-divided into different types of charges which reflect the way costs change with various features of the supply; e.g. standing charges, energy consumption, Maximum Demand and power factor amongst others.

The cost of generating and distributing electricity varies considerably with the time of day and season of the year. Unlike other energy sources such as coal, oil and gas, electricity cannot be stored economically in significant quantities. Consequently, although pumped storage schemes provide some potential for storage, the cost of supplying electricity to a consumer usually depends on the particular time and rate at which the energy is consumed.

For any given supply the maximum rate of consumption of electricity is termed the 'Maximum Demand'. Normally, Maximum Demand is regarded as twice the number of kilowatt hours (or kilovolt amp hours) consumed during any half hour. For charging purposes the highest demand in the month, quarter or year is used. Electricity tariffs are generally more complex than those used for the supply of, and charging for, other energy sources, because the cost of generating and supplying electricity to a particular consumer is influenced by Maximum

Demand, the actual number of kilowatt hours (kWh) or units delivered, and several other characteristics of the supply.

In cases where there is likely to be a large inductive load producing a lagging power factor (such as factories with a load consisting predominantly of electrically driven machinery) the Maximum Demand in kW may be adjusted by, for example, dividing it by the average lagging power factor in the charging period to reflect the higher costs incurred by this type of consumer. Where reactive power meters are installed (see Section 6.1 - 'Power factor') power factor penalties may be charged if the number of kVArh units exceeds 50% of the kWh units.

For consumers with Maximum Demands presently in excess of 100kW and where the consumer has elected to purchase their electricity from a supplier other than the local Regional Electricity Company, metering that records the levels of consumption every half hour has generally been installed. This type of metering allows the supply company to monitor the levels of usage, day or night, winter and summer. It is then possible for the supplier to compare consumption of individual sites with the overall supply on the National Grid during the same half hour periods. (This allows Maximum Demand charges to be based on site consumption during peak demands on the system.) In practice what generally happens is that at the end of the financial year, usually 31st March, the supplier is aware of the system peaks and the highest and the next highest either side of the peak. These three system peak demands are known as the 'TRIADS'. An individual site's demands occurring at the same time as the TRIADS are then averaged and charged for at the agreed rate.

5. Meters and meter reading

A feature of electricity usage is that the consumption can be accurately metered. As far as electricity bills are concerned the meter is provided and read by the Electricity Supply Authority. Bills based on these readings are sent to the consumer. Most consumers take these bills without question and although they might

wonder how the electricity has been used during the period covered by the bill, they take little or no action to find out the reasons for the levels of Maximum Demand, kWh usage, or power factor.

It is important that some attempt at analysing usage should be made and therefore regular reading of meters should be instituted. Fuel Efficiency Booklets No 1 - 'Energy audits for industry' and 'Energy audits for buildings' - give advice on this. There are various types of electricity meter including ammeters (A), voltmeters (V), meters reading in terms of kilowatt hours (kWh), kilovolt amp hours (kVAh) and reactive kilovolt amp hours (kVArh).

For consumers on tariffs with neither Maximum Demand nor power factor clauses, the simple kilowatt hour meter is normally used alone. Two types of display predominate, one having the pointer type dial and the other a cyclometer type dial (digital). See Figs 1 and 2.

These meters can also be constructed so that the amount of electricity used at normal rates and reduced rates are measured separately. An example, in the domestic and small commercial sectors, is the Economy 7 or White Meter.

The reading of the pointer type of meter can be confusing. The rule is to always read the lower number from the position the pointer is at. Unfortunately, because of the construction of the gear train in the meters, alternate pointers rotate in different directions. That is, some read anti-clockwise and others clockwise, naturally adding to the possibility of mis-reading.

- Always record the number which the pointer has passed. This is not necessarily the number nearest to the pointer.
- If the pointer is directly over a number, record this and underline it.
- If an underlined number is followed by 9, reduce the underlined number by 1.

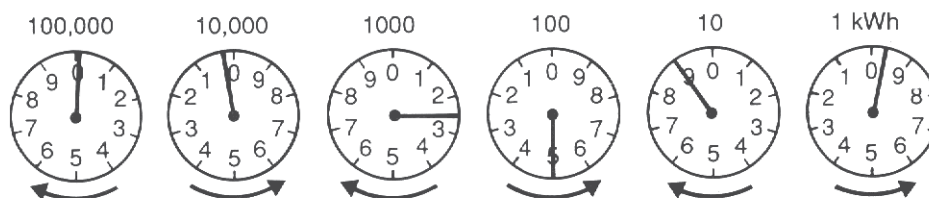


Fig 1 Meter with pointer dials

In Fig 1 the reading would be as follows:

The 100,000 dial pointer has hardly moved past (0): read 0
 The 10,000 dial pointer has moved past 0 but not reached 1: read 0
 The 1,000 dial pointer has moved past 2: read 2
 The 100 dial pointer is directly over 5: read 5
 The 10 dial pointer is directly over 9: read 9
 The 1 dial pointer is past 9 but not back to 0: read 9

The number which looks like 002599 at first will now be corrected to read 002489.

The reading of the digital meter (Fig 2) is relatively simple. The reading on the dial would be 123455 as the indicator has not reached 6 on the last register.

The simple kWh meter can be used to measure demand at any particular time if no other means exists. Meters carry a number on the identification plate showing revolutions per kWh which means how many times the revolving disc must rotate to indicate that one kWh has been consumed.

On a domestic meter this may be in the order of 300 revs/kWh. For larger users the figure will be less.

Taking an example of 20 revs/kWh, the disc will rotate 20 times in each hour for each kW of demand. Therefore for one minute it will rotate 20 divided by 60 that is one third of a revolution per minute for each kW.

If the revolutions for one minute are counted at 35, the demand over that minute will have been 35 divided by one third which is equal to 105 kW.

This is a useful means of carrying out spot checks on demand and in the absence of demand indicators can be used to log loads to produce a demand curve.

In the case of supply tariffs, where power factor comes into consideration, the simple kilowatt hour meter is not sufficient. In Section 6 on power factor, it is explained that the reading of a kilowatt hour meter will indicate the power actually consumed, whether or not the voltage and current are in phase.

The actual current to provide this power will vary depending on the power factor at the site. A meter which will indicate the amount actually supplied is needed by:

- The Supply Authority, to ensure it gets paid for what it supplies.
- The consumer, so that they can monitor their use and endeavour to bring the power factor towards unity and so contribute to optimising their costs for electricity.

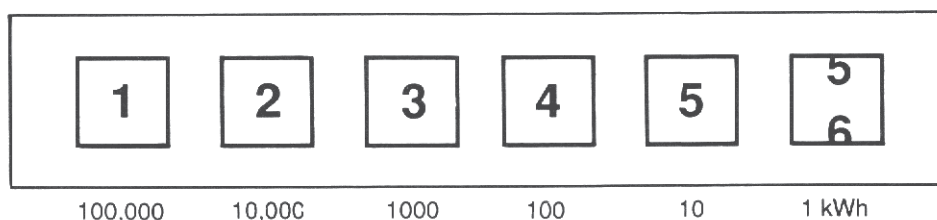


Fig 2 Meter units dial

6. Power factor and its correction

The electricity supplied by the Generating Companies or via the RECs is in the form of alternating current (ac). This means that the current varies with time in the form of a sine wave which repeats itself 50 times each second. Thus the frequency of the supplied current is 50 Hz.

In ac systems the current, and hence the power, is made up of a number of components. These are the currents taken by the resistive, inductive and capacitive elements of the power consuming load. In a resistive load the current will follow the voltage and hence is termed in phase with the voltage. Incandescent lighting and electric resistance heating are the most common forms of resistive load. For an inductive load the current is out of phase with the voltage and it lags behind the voltage. The most common inductive loads are induction motors. In a capacitive load the current is again out of phase with the voltage, but this time leads the voltage. The most common capacitive loads are power factor correction capacitors. Inductive or capacitive loads are commonly referred to as reactive loads. The combination of resistance and reactance is known as impedance and is denoted by the letter Z.

In practice most loads are not purely resistive, inductive or capacitive; for example the coils of an induction motor present an inductive load,

while the copper from which the coils are constructed presents a resistive load.

The significance of these different types of load is that true or useful power can only be consumed in the resistive part of a load, where the current is in phase with the voltage. The reactive components of the load only consume wattless or reactive power. The true power when added vectorially to the reactive power, gives the apparent, or total power. The power vectors are shown in Fig 3 where the reactive power is drawn at right angles to the true power. The apparent power is shown as the vector sum of these two powers.

True power is measured in watts (W) or more commonly in kilowatts (kW). The apparent power is measured in volt amps (VA) or kilovolt amps (kVA). The reactive power is measured in volt amps reactive (VAr) or kilovolt amps reactive (kVAr). The ratio of true power (kW) to apparent power (kVA) is known as the 'power factor'.

$$\text{Power Factor} = \frac{\text{True Power}}{\text{Apparent Power}}$$

For an ideal pure resistor the power factor would be 1.0, unity. For a pure inductor the power factor would be 0.0 lagging and for a pure capacitor 0.0 leading. From the triangle shown in

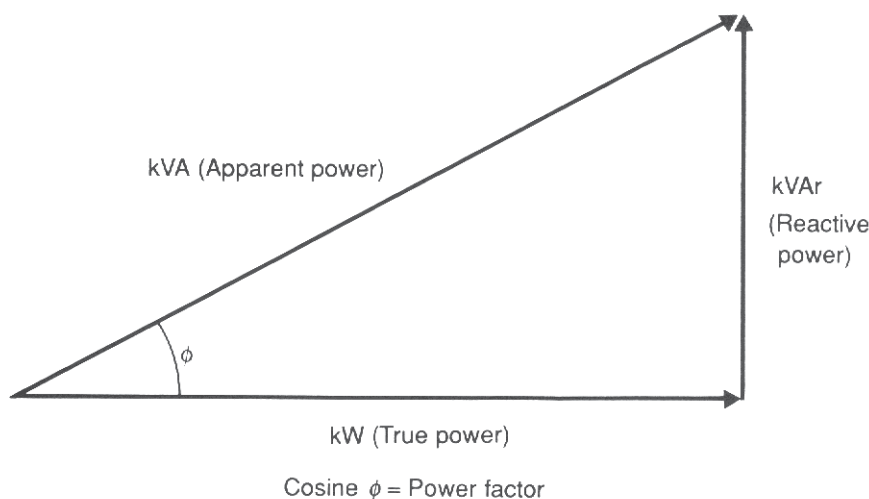


Fig 3 kW, kVA & kVAr relationship

Fig 3 it can be seen that the power factor is the cosine of the angle ϕ . The apparent power can be calculated by simply multiplying the measured volts by the measured amps. So, when the power factor of a load is known the true power can be calculated from the equation:

$$\begin{aligned}\text{True Power (kW)} &= \frac{\text{volts} \times \text{amps} \times \text{power factor}}{1000} \\ &= \frac{\text{volts} \times \text{amps}}{1000} \times \cos \phi\end{aligned}$$

When the power factor is unknown or varies, instruments which can measure true power directly should always be used.

6.1 Power factor

In many industrial and commercial electrical systems a great part of the load is provided by electric motors, discharge lighting including fluorescent tubes or other equipment with inductive reactance and a lagging power factor. Power factors of 0.7 or less are not uncommon in these situations.

A simple example showing the current required by a single phase electric motor is given below:

Example

Power supplied = 240 volts single phase
Motor input = 3 kW
Power factor = 0.7

By using the relationship shown above it can be shown that:

$$\text{Current} = \frac{\text{Watts}}{\text{Volts} \times \text{power factor}}$$

Substituting:

$$\text{Current} = \frac{3000}{240 \times 0.7} = 17.86 \text{ amps}$$

However, if the power factor was 1.0, usually known as unity, the current required would be:

$$\text{Current} = \frac{3000}{240 \times 1.0} = 12.5 \text{ amps}$$

Similar calculations can be carried out with three-phase supplies.

From the above example it can be seen that the more the power factor departs from unity, the greater the current required to provide the useful power. The effect of this on the equipment used to supply the motor is considerable. The sizes of switchgear, fusegear, cables and transformers will all have to be greater. This obviously results in increased costs.

As an example of this, it can be shown that by ignoring power factor, the sizes of the supply equipment may have to be increased as follows:

Supply voltage = 415 volts 3 phase

Total load = 260 kW

Power factor = 0.7

Total current = $\frac{260 \times 1000}{415 \times 0.7 \times \sqrt{3}} = 517 \text{ amps}$

The switchgear to supply this current would probably be rated at 600 amps and the transformer rated at 400 kVA, (although 500 kVA is a more standard size and would probably be chosen) with cables having a minimum cross sectional area per copper conductor of 300 mm².

If the power factor was corrected to as near unity as practicable, the total current would fall to 362 amps and the switchgear could then be rated at 400 amps. The kVA would come down to 260 kVA thus allowing the use of a standard 300 kVA transformer, whilst the cable size could be reduced to 185 mm². In the transmission of the current itself, heating losses will be greater at low power factor (they vary in proportion to the square of the current and are known as I²R losses, where I = current and R = resistance) and the voltage drop will be in accordance with the relationship given by IZ (where Z is impedance, defined earlier). As I²R losses will be higher for smaller cables, sizing a cable over minimum can be cost effective in some cases.

It is evident that losses in the electricity system due to poor power factor will incur additional costs and that these will have to be reflected to some extent in charges to consumers. This is implemented by metering the Maximum Demand in kVA or by applying a power factor component in the tariffs.

Most commercial and industrial loads usually have lagging power factors. Power factor correction in these cases means introducing some form of capacitance (capacitor) or the use of special types of motors. Although the use of static capacitors is widely known, they may not always be the most satisfactory or economic solution and the advice of the REC or other qualified person should be sought. However, depending on the tariff in use, the improvement of power factor beyond a certain point can produce diminishing financial returns which may not be commercially acceptable.

The tariff charge example and Table 1 show how capacity and demand charges reduce with an increasing power factor and also the amount saved per annum per additional kVAr capacity (see example calculation below Table 1).

In cases where the greater part of the normal load is near a power factor of 1.0 (due to it comprising mainly lighting or resistance heating) and it is only at periods of low load that the power factor reduces to less than 0.8 it may not be economic to fit power factor correction. Each case should be considered on its merits and independent advice should be sought where appropriate.

6.2 Power factor correction

It has already been shown that low power factor can cause increased costs and it will be useful to look at this problem in more detail.

6.2.1 Induction motors

In industry and commerce the widely used induction motor is the most likely cause of low power factor. Even when fully loaded, induction motors can have power factors below 0.6, and on low load the power factor can approach 0.1, with the wattless or magnetising current being as much as 90% of the total current supplied. In particular the power factor properties of small motors are not as good as those of larger machines. However, an underloaded large motor will have a lower power factor than a smaller one at full load doing the same job.

Example

In meeting a 3.7 kW (5 hp) load, a 3.7 kW motor which is working at full load will have a higher power factor (over 0.9) than a 22 kW (30 hp) motor meeting the same load (under 0.6).

The speed of motors also has a role to play and a higher speed motor always has a better power factor than a low speed motor. The above can be summarised in the following points:

- Well designed motors may cost more but will usually have a better power factor than lower priced machines. (These motors are discussed in more detail later).
- High speed motors should be used in preference to low speed machines.
- Oversizing of motors should be avoided. The minimum size compatible with safe and efficient working should be selected (see Section 8.2.1 - 'Oversized Motors').
- Motors should be worked up to a maximum loading and therefore individual motors would be preferred to a single motor driving several loads where the loads are not always at a maximum.

6.3 General

It is normally better to correct the power factor for inductive loads such as induction motors at the motor itself. When this is done, all wiring, all the way back to the generating station itself will be relieved and voltage drop and resistance losses will be reduced. If the capacitor is fitted to the motor there will be no need for additional switchgear as the motor switch also controls the capacitor.

An example of power factor correction is shown in Fig 4. When the correct size of capacitor is fitted the power factor is greatly improved and is virtually constant with all loads over 30% of full load.

Example tariff charges

Tariff - Maximum Demand differential monthly

For each of the first 50 kVA of the chargeable capacity £1.50

For each kVA of chargeable capacity in excess of 50 kVA £1.20

Each month for each kVA of Maximum Demand in that month

March to October inclusive £0.90

November and February £3.45

December and January £9.20

Customer Billing

Assuming that the load is a constant 100 kW at 0.6 power factor the kVA at this maximum load is $100/0.6 = 167$ kVA so that the capacity and demand charges will be as follows:

Capacity Charges

£1.50 x 50 kVA x 12 months = £900.00

£1.20 x 117 kVA x 12 months = £1,684.80

= £2,584.80

Demand Charges

£0.90 x 167 kVA x 8 months = £1,202.40

£3.45 x 167 kVA x 2 months = £1,152.30

£9.20 x 167 kVA x 2 months = £3,072.80

= £5,427.50

Total Annual Charge = £8,012.30

Table 1 Example of the effects of increasing power factor

Power Factor	Capacity and Demand Charges £	kVar*	£/kVar saving/annum by increasing to next power factor in table
0.6	8,012	133	36.3
0.7	6,887	102	31.3
0.8	6,043	75	24.3
0.9	5,386	48	10.8
1.0	4,870	Nil	-

*kVar can be calculated as follows:

$$kVar = \sqrt{\left(\frac{\text{Actual load (kW)}}{\text{Actual Power Factor}}\right)^2 - \left(\frac{\text{Actual load (kW)}}{\text{Unity Power Factor}}\right)^2}$$

For example, for a 100 kW load with a power factor of 0.8

$$kVar = \sqrt{\left(\frac{100}{0.8}\right)^2 - \left(\frac{100}{1}\right)^2} = \sqrt{15625 - 10000} = \sqrt{5625} = 75$$

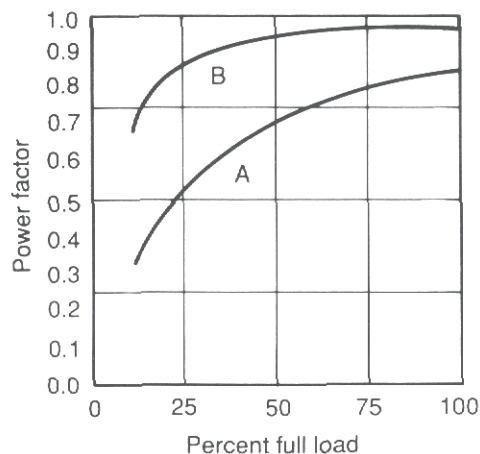


Fig 4 Fitting a power correction capacitor to an induction motor
Curve A - No capacitor
Curve B - Capacitor fitted

Over correction of power factor is avoided by selecting the correct capacitance and by the automatic switching on of the capacitor with the motor. It must be borne in mind that individual power factor correction is more appropriate for constant loads.

As mentioned in Section 6.1, central correction of power factor may be economic where there are small items of plant with fluctuating usage, not all being operated at the same time (having a high diversity).

Further correction to the power factor can be made manually, by switching in smaller capacitors to suit particular load conditions. Care must be taken that over correction is not made due to low loading.

Automatic switching of capacitors is necessary over 40 kVar. Such automatic control is a well-established technique which ensures that over correction does not occur.

Capacitors should be provided with sufficient ventilation to avoid high temperatures. In all cases of doubt as to operating temperatures the suppliers should be consulted.

7. Load Management

As well as reviewing the foregoing points on good housekeeping, maintenance and power factor correction, the characteristic of the resulting total site load itself should be looked at.

7.1 Areas of Load Management

There are two areas of load management - Supply Industry Load Management and Load Management by the consumer locally.

7.1.1 Supply Industry Load Management

Contracts can be entered into, usually between the Generating Companies and their customers, whereby in return for a reduction, generally in the Maximum Demand charges, loads are shed from the system at times of system peak demand. It is normal for customers to be given notice, the day before, of the need to reduce load at a particular time the following day and in certain cases, by a specified amount. It is unusual for customers with a peak demand of less than 5 MW to be offered the facility of Load Management. The length of Load Management periods on a single day rarely exceed 1.5 hours.

Regional Electricity Companies also achieve Load Management, usually by bringing on line relatively small (1.5 MW) standby generators for short periods.

7.1.2 Local Load Management

This is carried out by the consumer on his own loads. The benefits of good Load Management include:

- the possibility of bringing in new items of equipment without undue costs
- the average load carrying capacity of the electricity system is increased
- the total electricity consumption can increase without a concurrent increase in Maximum Demand
- a reduction in electricity charges or the possibility of using more for the same total cost.

In most cases there is, however, limited scope for local load management in buildings.

7.2 How Maximum Demand is determined

From Section 4 - 'Electricity supply costs and tariffs' - Maximum Demand is normally regarded as twice the highest load taken during any half hour in any month.

Example

If 100 kWh were consumed in a half hour period the Maximum Demand would be:

$$\frac{100 \text{ kWh}}{0.5 \text{ h}} = 200 \text{ kW}$$

As this figure is arrived at whether or not the load was constant there is the effect of averaging out any load fluctuations.

Load controllers can be designed to take advantage of this by taking steps to reduce load if a predetermined Maximum Demand looks as if it will be exceeded.

7.3 Load factor

For the purposes of electricity supply, load factor is defined as the ratio, expressed as a percentage, of the average load to the maximum load, during

some interval of time. In general plant terms, annual load factor can have a different meaning and is the ratio, expressed as a percentage, of the actual load to the maximum possible load - bearing in mind the maximum rating of the plant - during some interval of time.

In all types of operation, high load factors are economically desirable, but this is especially so with electrical loads where tariffs are geared to good Load Management. Fig 5 shows the electrical demand averaged out over half hour periods of a plant.

As electrical load factor has been defined as:

$$\text{Load factor} = \frac{\text{Average demand}}{\text{Maximum demand}} \times 100\%$$

it will be evident that, if the Maximum Demand can be reduced by loads being moved to periods of low demand, the amount of energy used and hence the average demand, may stay the same, but the load factor will be improved - see Fig 6.

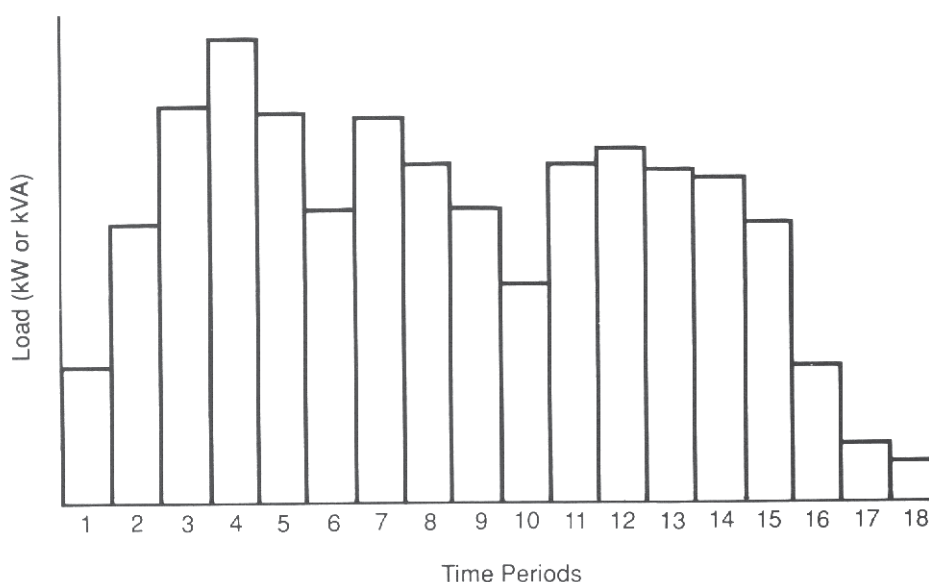


Fig 5 Load profile without load factor control - Load factor 60%

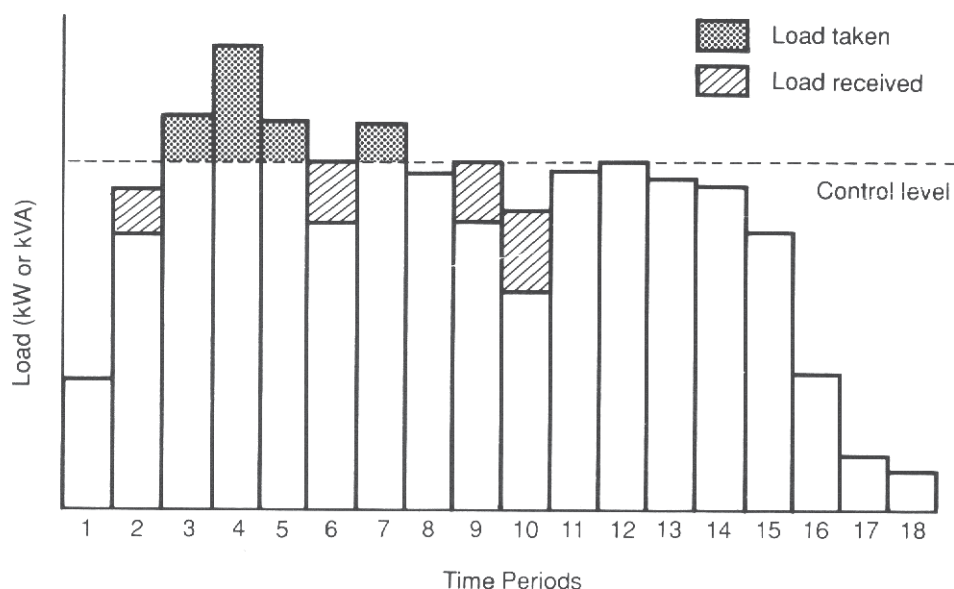


Fig 6 Load profile with load factor control - Load factor 80%

The load factor for the load shown in Fig 5 was 60%, but in the case of Fig 6 it has been increased to 80% by moving loads to periods of low demand. In this example it would in fact be possible to use 6% more electricity for the same total cost because of the reduction in Maximum Demand charges.

8. Reducing motor loading

The electric motor is probably the most widely used piece of electrical equipment in building services. In industrial buildings it accounts on average for 65% of total electricity consumption. The motor presently in most general use is the 3-phase induction motor. It can operate at different speeds depending on the number of poles and offers a relatively cheap and versatile source of rotating mechanical power.

Most motors are designed to run with highest efficiency at their full load but they are rarely required to work in this way.

8.1 Motor sizing

The maximum load for which motors are installed may be considerably less than the motor rating. There are a number of reasons for this, some of which originate in the plant itself - for example, allowances in the mechanical design for unexpected contingencies. Above and beyond this, it is common practice to oversize the electric motors in an endeavour to ensure reliability and allow for possible changes in plant operation.

Oversizing motors differs from application to application. A typical cross-section indicates that average actual loading of motors is probably in the order of 65%. In many cases the end user has not been able to choose the electric motor; it comes as a package with the equipment and, as the equipment supplier must assume the worst, i.e. the heaviest duty, the motor is sized accordingly. It may be possible for the motor to be sized more in line with its actual maximum load. In many building applications, such as fans, the motors are considerably oversized.

Efficiencies of motors vary with size (rating), loading and manufacturer. Typical standard motors may have efficiencies at full load between 55% and 95% depending on size and speed -

the lower the speed the lower the efficiency, particularly in the case of small horse power motors (below 1.5 kW). The efficiency curves of standard motors vary but Fig 7 shows that typically efficiency is reasonably constant down to 75% full load and may lose less than 5 percentage points down to 50%. Thereafter, the efficiency starts to fall rapidly. Note that whilst the shape of the curve is similar for different motor ratings, the actual efficiency values generally fall with decreasing motor rating.

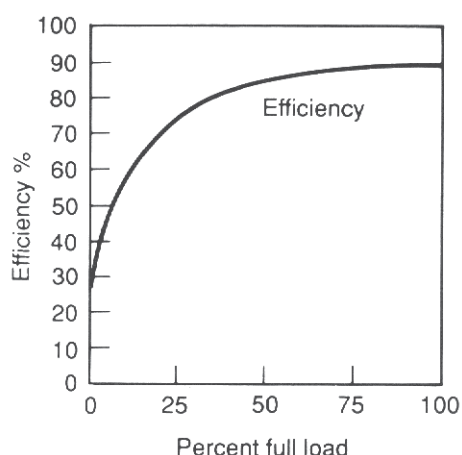


Fig 7 Standard induction motor efficiency against load

It follows that, provided motors are run at a reasonably constant load, oversizing by up to 30% will not seriously affect efficiency. However, if the load is fluctuating and rarely achieves 75% full load, the efficiency can be seriously affected. For example with a curve as shown in Fig 7 and a 10 kW constant maximum load, a 15 kW motor would be running at 66.6% full load and the loss of efficiency would be about 1% compared with using the properly sized motor. However, if the maximum load was still 10 kW but the load was frequently only 3 kW, the efficiency of a properly sized motor at this load would be above 80%, whilst the 15 kW motor would be running at less than 70% efficiency.

Power factor is also adversely affected by low loading. Fig 8 shows a typical curve. It will be seen that power factor falls off more rapidly than does efficiency; consequently, if motors are

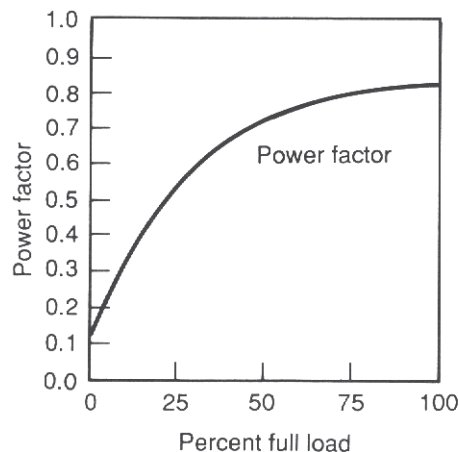


Fig 8 Induction motor power factor against load

lightly loaded, i.e. oversized, the power factor correction needs to be greater, involving higher cost.

Oversizing therefore:

- increases the capital cost of the motor itself;
- increases the capital cost of matching switchgear and wiring;
- increases the capital cost of power factor correction equipment;
- increases the cost of the electricity itself due to lower efficiencies.

8.2 Motor replacement

Normally motor replacement will occur because existing units are beyond economical repair. Perhaps, in some cases, repairs are still carried out because of delivery problems, but in the main it is the cost of a new motor and the cost of repair that are the chief criteria.

8.2.1 Oversized motors

From Section 8.1 the disadvantages of oversized motors are apparent. Both power factor and efficiency are adversely affected and with long periods of idling, matters become worse. A programme should be instituted throughout the site to ascertain what actual maximum loads are on a particular motor. If no actual power meters

are available, electrical energy efficiency analysers can be hired for the investigation, or the method described in Section 5 - 'Meters and meter reading' - using a kWh meter can be adopted.

This should be done for every motor and, having logged these loads, the capacity of the motors should be compared with the actual maximum load figures.

The stock of motors should be reviewed to see if there is a possibility of switching motors so that the larger motors which are under-loaded (or oversized) can be replaced by smaller capacity motors further down the load range. These in turn should be examined for replacement by smaller motors still.

Whilst in ideal circumstances the moving of motors should mean that only a few small motors need be bought to fill vacancies on the bottom end of the scale, it may be in some cases that, because of the problem of mountings and short peak loads, motors cannot be replaced by smaller units. In these cases replacement by high efficiency motors should be considered.

8.2.2 High efficiency motors

Losses in induction motors consist of those that vary with the load and those that are constant whatever the load. The split is about 70% and 30% respectively of full load losses, i.e. when a motor is running at full load.

The electrical load losses include the rotor resistance loss, the stator resistance losses and stray losses usually regarded as losses in or near the rotor conductor slots. When the motor is running with no load these copper losses are very small. However, once a load is applied, these losses will increase as the square of the motor current, hence copper losses are known as I^2R losses. In addition there are iron losses in the magnetising circuit of the motor. These losses, known as eddy current and hysteresis losses, are related to voltage and are, therefore, constant, irrespective of motor load. The mechanical losses are the friction in bearings, the turbulence around the rotor as it rotates and the windage of the cooling fan. Motors designed to minimise all these losses are termed 'high efficiency motors'.

Another factor which may be taken into account in the design, is consideration of 'normal' loading. If it can be shown that the application of a motor, whilst requiring full power, at most times runs at say 60% full load, the motor could be designed so that its highest efficiency was at this load, rather than full load output.

Design to minimise electrical losses will mean increased cost in terms of more materials. As I^2R losses (heat losses) will be reduced, the cooling fan can also be reduced (so reducing windage loss). At present the total cost will be higher than for a standard motor, but this may change as the price differential between standard and high efficiency motors is decreasing. Typical high efficiency motor and standard motor efficiency curves are shown in Fig 9.

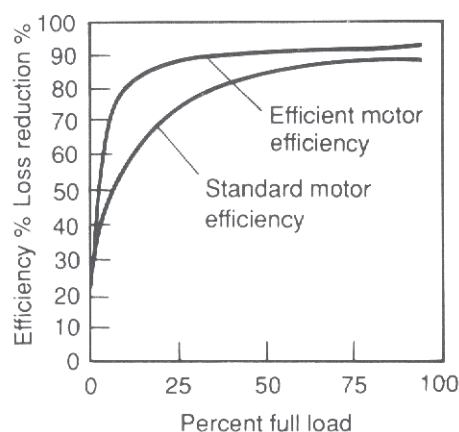


Fig 9 High efficiency and standard motor efficiency against motor load

Factors to be taken into account when looking at the economics of high efficiency motors are:

- The motor load in terms of rated load and how the load fluctuates. From this the correct size of motor can be established and also hopefully some idea of average loading.
- How the efficiency of the standard motor compares at the average load with the high efficiency motor, for the same motor rating.

- Times and hours of operation during the year.
- Electricity tariffs - including kWh rates and Maximum Demand charges.

Where a motor requires replacement, or is for new plant, the payback on the premium for a high efficiency motor is between 6 months and 2 years, depending on whether the motor is being run continuously over the year, or in a single shift, five day week situation. Further information is available in the Energy Efficiency Office (EEO) publication Good Practice Guide 2 - 'Guidance Notes for Reducing Energy Consumption Costs of Electric Motor and Drive Systems'.

8.2.3 Variable speed drives

It is estimated that around 55% of 3-phase ac motors are fitted to fans or pumps. The flow from most fans and pumps is controlled by restricting the flow by mechanical means; dampers are used on fans, and valves are used on pumps. This mechanical constriction will control the flow and may reduce the load on the fan or pump motor, but the constriction itself adds an energy loss which is obviously inefficient. Hence if the flow can be controlled by reducing the speed of the fan or pump motor this offers a more efficient means of achieving flow control.

In fact the saving is greater than might initially be expected. As the speed of the fan or pump is reduced, the flow will reduce proportionally, while the power required by the fan or the pump will reduce with the cube of the speed.

Example

If the flow can be reduced by 20% the corresponding speed reduction, to 80% of normal speed, will reduce the power to:

$$0.8^3 = 0.8 \times 0.8 \times 0.8 = 51.2\%$$

This level of potential energy saving makes the use of a Variable Speed Drive (VSD) to control flow one of the most important, cost-effective investments in energy efficiency which can be considered for motors. Paybacks of under two years are the norm with paybacks of under one year possible.

It has always been possible to control the speed of ac motors, but in the past this was only justified for exceptional cases. In recent years, modern power semiconductors and microprocessors have allowed the introduction of electronic VSDs which have improved performance and reliability over earlier systems while reducing the equipment costs. Hence a range of motors can now be considered for retrofitting with a VSD based on the economics of the electricity savings alone.

It is important to establish the operating conditions for a particular motor before selecting which VSD to use. The details of motor rating, operating hours, flow requirements and electricity costs will determine which types of VSD can be considered. It is not possible to cover all the options in this booklet. Further information is available in the EEO publication Good Practice Guide 14 - 'Retrofitting ac Variable Speed Drives'.

VSDs have been successfully used in a range of applications. Examples include motors on boiler forced draught fans, air conditioning chilled water pumps, cooling tower fans, combustion fans and refrigerant pumps.

9. Lighting

In commercial and industrial buildings lighting can be a substantial energy consumer; in some cases, such as office buildings, lighting costs can exceed heating costs. An important and often overlooked contribution to lighting is natural daylight. Good building design can maximise the use of daylight whilst avoiding adverse effects such as summer overheating.

The application of current best practice can reduce lighting energy consumption, and hence costs, significantly; demonstrated savings have frequently been in the range 30 to 50%.

Lighting energy is often wasted through ignorance of the actual situation. Nowhere is good housekeeping more important than in lighting applications.

9.1 Lamps

Most industrial and commercial buildings are illuminated by fluorescent or other forms of discharge lighting. Where tungsten filament lamps are in use, considerable improvements may be achieved in both illumination and energy consumption by substitution with compact fluorescent lamps. Where large numbers of compact fluorescent lamps are used, there may be a need for some degree of power factor correction, as power factor may otherwise be quite low.

Highlighting has traditionally been provided by tungsten spotlights. Tungsten halogen lamps can be used effectively for this application and provide typically a 50% reduction in energy consumption.

Standard 38 mm diameter fluorescent tubes have now been superseded by 26 mm diameter tubes. In luminaires with switch-start control gear, the smaller tube can be substituted directly and will provide approximately the same light output for around 8% less electricity.

Substitution is recommended when existing lamps fail or are scheduled for replacement.

For illumination of very large areas, high pressure sodium or metal halide lamps are available. These are recommended for large, high areas such as factories, and are also useful for exterior lighting.

9.2 Ballasts

All discharge lamps require ballasts to control the lamp; the ballast also usually corrects the power factor, the notable exception to this being some compact fluorescent lamps. Traditionally the ballast has consisted essentially of a wire-wound choke; energy losses of 15-20% of total consumption are the norm in such control gear. Newer "low-loss" ballasts are more efficient, but may not always be suitable for retrofitting to existing luminaires.

High frequency electronic ballasts can realise savings of around 20%. Fluorescent tube efficacy (light output per watt input) increases with frequency, so energy savings result partly from this and partly from lower losses in the ballast. Starting conditions for the lamps are

softer and switching has less effect on lamp life. There is also some evidence that high frequency lighting improves occupant comfort over conventional mains frequency fluorescent lighting.

9.3 Luminaires

Modern luminaire designs are more efficient than older luminaires. Refurbishment of old installations using modern equipment can result in substantial energy savings in addition to improved visual conditions. Care should be taken, since the appearance of an area may be changed and some form of small-scale pilot is usually worthwhile.

9.4 Lighting controls

Appropriate controls can yield substantial improvements in lighting energy efficiency. These improvements arise principally from better use of available daylight to reduce electric lighting use and switching off lighting when a space is unoccupied. The savings which can be made depend greatly on the level of daylight available and the occupancy pattern of the building.

Four basic methods of lighting control are available: time-based control; daylight-linked control; occupancy linked control; and localised switching. Control systems can use a combination of these techniques and occupant switching to achieve worthwhile energy savings.

It is important that the occupants of a space are aware of the existence of the automatic elements of the overall lighting control system, how it works and how they can interact with it. This is particularly important with retrofit installations.

Substantial savings can be achieved by appropriate lighting controls. In offices, for example, reductions of 30 - 50% in lighting energy consumption are typical with payback periods of 2 - 3 years; savings as high as 70% and payback periods of under 2 years have been realised in installations such as warehouses.

These energy efficiency measures are summarised in Tables 2 and 3. For more detailed information on aspects of energy usage in lighting, refer to Fuel Efficiency Booklet No 12 - 'Energy Management and Good Lighting Practices'.

Table 2 Lighting related energy efficiency measures and building sectors						
Energy efficiency measure	Offices	Education	Industry	Hospital	Retail	Leisure
Optimise daylighting inside building	X	X	X	X	X	X
Install more efficient lamps:						
• replace tungsten with compact fluorescent	X	X	X	X	X	X
• replace 38mm tubes with 26mm tubes (switch start only)	X	X	X	X	X	X
• replace tungsten display lighting with tungsten halogen or high pressure discharge lamps	X	X			X	X
Install more efficient luminaires	X	X	X	X	X	X
Install high frequency ballasts for fluorescent lamps	X	X	X	X	X	X
Regular maintenance and cleaning of lamps and luminaires	X	X	X	X	X	X
Localised lighting instead of general lighting	X		X			
Encourage manual switch off when lighting is not needed because space is unoccupied or daylight is adequate	X	X	X	X	X	X
Fit localised switching close to task areas	X		X			X
Install automatic lighting controls	X	X	X	X	X	

Table 3 Lighting related energy efficiency measures: Energy savings and typical payback periods			
Energy efficiency measure	Cost (£)	Energy savings (%)	Payback (years)
Replace tungsten lamps with compact fluorescent lamps	12 - 20 each	40 - 70	1 - 3
Replace 38mm fluorescent tubes with 26mm tubes (switch start only)	3 - 5 each (same price)	8	<2
Replace tungsten spotlights with tungsten halogen	15 - 30 each	30 - 75	2 - 3
High frequency ballasts for fluorescent lamps	15 - 50 per luminaire	15 - 20	5 - 15
Replace opal diffusers or 'eggcrate' louvres with prismatic panels or specular reflectors	25 - 60 per luminaire	20 - 50	2 - 6 if fewer luminaires needed
Install automatic lighting controls	-	20 - 50	2 - 5
Localised instead of general lighting	-	60 - 80	4 - 8

10. Refrigeration

Refrigeration systems are widely used in cooling, storage and air conditioning applications. The key to efficient operation of refrigeration systems is that those responsible for their design, purchasing, installation and use understand the basic principles of operation. Additionally, refrigeration equipment must be regularly monitored to ensure that it is operating to specification. It is quite common for plant to use 30% more energy than it should and for this to go unnoticed for long periods of time.

This booklet provides a very basic overview of refrigeration. More detailed information can be found in Fuel Efficiency Booklet 11 - 'The economic use of refrigeration plant'.

10.1 Basic refrigeration principles

The majority of refrigeration systems in the UK operate by the vapour compression process. This process is shown schematically in Fig 10.

Energy is absorbed by liquid refrigerant boiling in the evaporator. This energy comes from the

substance being cooled. The refrigerant vapour is then compressed by the compressor (usually driven by an electric motor), raising both the pressure and temperature. The compressed vapour is cooled and condensed in the condenser, giving up its latent heat, usually to air or water. The liquid refrigerant then passes through the expansion valve from high to low pressure to complete the cycle.

10.2 Refrigeration system components

There are four major components to a refrigeration system, as shown in Fig 10: evaporators, compressors, condensers and expansion devices. The different types are outlined briefly below.

10.2.1 Evaporators

There are three principal types of evaporator:

- direct expansion (or 'dry expansion');
- flooded shell and tube;
- recirculation.

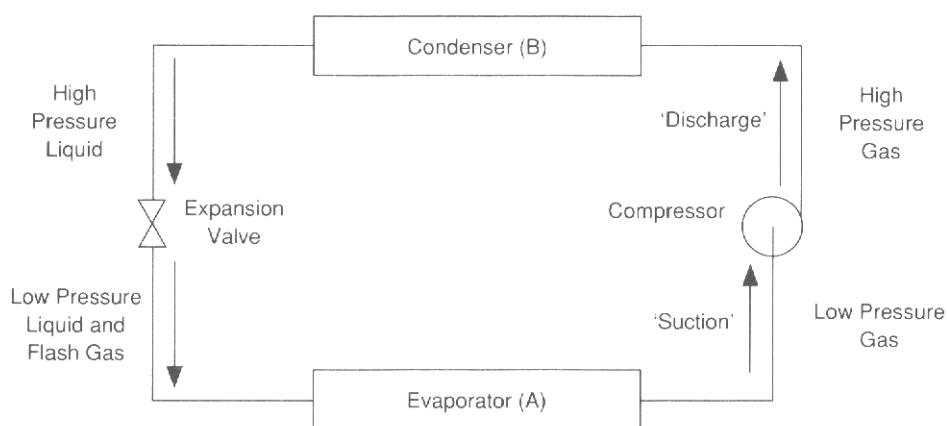


Fig 10 Basic vapour compression circuit

In direct expansion evaporators the refrigerant is completely evaporated by the time it reaches the end of the evaporator. This type of evaporator is almost always used in association with a thermostatic expansion valve - see Section 10.2.4. Flooded shell and tube evaporators are widely used for cooling liquids, the liquid being cooled in the tubes by refrigerant boiling on the shell side. In recirculation evaporators, the evaporated vapour is apart from the liquid refrigerant in a separate vessel and the liquid is recirculated to the evaporator.

Evaporators operating below 0°C can accumulate frost on their surface. This can seriously reduce efficiency and so any such frost must be removed periodically. Efficient defrosting requires:

- determination of when defrosting is required;
- use of an efficient method of heating the ice;
- termination of defrost after the ice is melted and the water drained off.

10.2.2 Compressors

Compressor/motor configurations are described as open, semi-hermetic or hermetic. An open compressor is totally separate from its drive motor, whereas a hermetic compressor forms a completely sealed unit with the motor.

Semi-hermetic compressors are connected to the drive motor but can be accessed, unlike the hermetic version.

Compressor performance data are normally presented as either graphs or tables of duty and power for a range of evaporating and condensing temperatures. Correction factors are needed to obtain data which corresponds to actual operating conditions; it is essential that users obtain this information.

There are several different types of compressors: reciprocating (the most common); rotary vane; twin screw; single screw; and centrifugal. All have different characteristics and different factors to consider for efficient operation.

At less than full load the theoretical maximum efficiency of a refrigeration system rises. Against this, however, losses from causes such as increased friction reduce the efficiency.

Centrifugal and screw compressors can be very inefficient at low loads. In some cases, variable speed motor drives may be appropriate to improve efficiency of operation.

10.2.3 Condensers

There are three main types of condenser in widespread use:

- water-cooled shell and tube;
- air-cooled;
- evaporative cooled.

Water-cooled shell and tube condensers are used for all refrigerants, usually with refrigerant on the shell side and water in the tubes. Cooling towers are the usual source of water. Poor efficiencies are usually caused by mineral deposition or algae growth; these can be controlled by water treatment and dosing with biocides respectively.

In air-cooled condensers the refrigerant is condensed inside finned tubes by air passing over the surface. Evaporative condensers are similar but here the tubes are wetted on the outside and air is blown over them to produce cooling by evaporation.

One major possible source of inefficiency in condensers is the presence of non-condensable gas, e.g. air in the refrigerant system. Over time, large amounts of such gas may find their way into the refrigerant system and this can increase operating costs by 10% or more.

10.2.4 Expansion devices

In principle, the expansion valve is a simple item of equipment to reduce high pressure liquid refrigerant to a lower pressure. There are four main types:

- high pressure float valves;
- low pressure float valves;
- thermostatic expansion valves;
- electronic expansion valves.

The operation of expansion valves in practice is quite complex and the reader is referred to a more detailed reference, such as Fuel Efficiency Booklet 11, for a full operating description. It is important on systems with float valves that refrigerant levels are regularly checked.

11. Monitoring and Targeting

Most buildings have scope for reducing energy consumption. Monitoring and Targeting (M&T) is a structured approach to energy management which can help to identify where savings can be made in operating plant and equipment. M&T also provides the information necessary to evaluate proposed changes in equipment. Finally, M&T can spot deterioration in equipment performance before operators are aware of anything being amiss.

'Monitoring' and 'Targeting' are two distinct activities. There are five essential steps to a Monitoring Programme.

1. Measure the electricity consumption of major equipment items.
2. Relate consumption to influencing factors, e.g. weather for heating equipment.
3. Compare actual consumption with what should have been used - the standard.
4. Report energy performance to the individuals responsible.
5. Take action to reduce consumption and maintain it at the lowest practical level.

These steps are designed to tell all staff involved with energy use about their energy consumption and costs, and to encourage them to use their own knowledge to make savings. Some additional metering may be necessary initially and a number of software packages are available to assist with M&T implementation.

The Targeting stage builds on the Monitoring process, by setting target standards for energy consumption and taking additional steps to achieve those standards. This can be limited to changes in operating procedures or may involve new equipment installation and significant capital expenditure.

Frequently energy costs can be reduced by 10% or more as a result of implementing a rigorous M&T programme.

12. Case studies

12.1 Automatic warehouse light switching system

A major automotive parts manufacturer has a central facility for storage of parts before their distribution to local dealers. These parts are stored in bins in a system of palletised racking covering an area of over 37,600 m². The aisles are up to 9 m in height and 55 m in length and are arranged in 7 main blocks. Components are retrieved from the bins by order-picking trucks, and replenishing trucks are used to move the bins around within the aisles. Illumination is provided by rows of fluorescent tubes mounted above each aisle. The random nature of occupancy meant that the lighting was previously in operation for the entire working day.

An automatic light switching system, using microwave Doppler shift sensors to detect motion, was installed. Sensors were fixed above the level of the racks at either end of each aisle, giving full coverage of each aisle area. Once movement is detected within the aisle, the lighting in that aisle is switched on and remains on for a period of time after movement has ceased. This delay time allows for periods of inactivity while a truck is within the aisle and can be adjusted from 30 seconds to 30 minutes. In this case the delay time used was 3 minutes 45 seconds.

Control points for the lighting controls are located adjacent to existing banks of light switches and key access to the control allows the automatic system to be overridden if necessary. The control system was installed and commissioned in 1986. Previously the annual lighting energy use amounted to 1,571,000 kWh; this was reduced by 70%. The reduction in hours of use of the lighting also reduced the need for relamping. The cost of the system was around £75,000 giving a simple payback period of 1.8 years.

12.2 Variable speed drive on a boiler fan

A large hospital with three high output steam boilers installed an electronic variable speed drive to control the speed of the forced draught fan motor on the boiler that, almost continuously, provided the main heating output. Motor electricity consumption per lb of steam produced fell by almost 70% and optimum boiler combustion efficiency has been maintained over long periods, due to the repeatability of fan speed commensurate with boiler firing rate.

The payback from energy savings achieved against an investment of £7,100 was between 10 and 11 months. Details of the system and the results achieved are contained in the EEO's Best Practice programme Good Practice Case Study No 35 - 'Variable speed drive on a boiler fan'.

12.3 Lighting controls in retailing

The Plymco Superstore, belonging to Plymouth and South Devon Cooperative Society, has a sales area of 2,000 m². The lighting is provided by 274 twin 60W lamps, 1.5 m luminaires equipped with high frequency electronic ballasts, providing an illuminance of 1000 lux. The installation is controlled by a microprocessor-based Energy Management System, which reduces the illuminance for activities such as restocking the shelves when the shop is not open to the public. The total installed lighting load is 35.9 kW, including the requirements of the control gear. This scheme was given the top award for new lighting schemes in EMILAS 1989 (Energy Management in Lighting Award Scheme).

12.4 High frequency fluorescent lighting

The 1991 winner of the Energy Management in Lighting Awards (EMILAS) Industrial Section achieved a 25% saving in energy consumption whilst doubling the illuminance level in its main machine shop, where high precision engineering takes place.

The new lighting scheme is based on very controllable high frequency fluorescent fittings, divided into ten zones with photocell control, to obtain maximum benefit from natural daylight.

The payback on the investment made in the new scheme is expected to be not greater than 36 months.

13. Summary

Efficient use of electricity in buildings can produce significant savings in energy consumption and associated costs. In the case of an existing building, the basic design has already been completed and scope for energy efficiency measures is restricted to upgrading and retrofitting.

In almost all cases there is immediate scope for savings from simple housekeeping and adequate maintenance of existing equipment. Other areas where substantial savings can be realised are:

- **Lighting:** this is generally the largest electricity consumer in commercial buildings and savings of up to 70% of consumption can be realised from energy efficiency measures.
- **Refrigeration and air-conditioning:** many of these systems operate at below optimum efficiency, a situation which can continue unnoticed for considerable periods of time. Correction of these inefficiencies can realise savings of around 20-30%.
- **Motors and drives:** the motors in packaged plant are often oversized for the actual applications in which they are used. Variable speed drives and correct motor sizing can achieve savings of over 50%.

Many of the measures to reduce electricity consumption in buildings require little or no capital expenditure and those which do often achieve payback periods of one to two years.

14. Sources of further information

• *EEO Publications:*

Fuel Efficiency Booklet 12	- Energy management and good lighting practices.
Fuel Efficiency Booklet 10	- Controls and energy savings.
Good Practice Case Study 130	- Reducing electricity consumption and costs in hospitals

Copies of the above publications and other literature applicable to energy efficiency in buildings are available from:

Enquiries Bureau
BRECSU (Building Research Energy
Conservation Support Unit)
Building Research Establishment
Garston
Watford WD2 7JR
Tel No: 01923 664258 Fax No: 01923 664787

Good Practice Guide 2	- Guidance notes for reducing energy consumption costs of electric motor and drive systems.
Good Practice Guide 14	- Retrofitting ac variable speed drives.
Good Practice Guide 42	- Industrial refrigeration plant: energy efficient operation and maintenance.
Good Practice Case Study 35	- Variable speed drive on a boiler fan.
Fuel Efficiency Booklet 9	- Economic use of electricity in industry
Fuel Efficiency Booklet 11	- The economic use of refrigeration plant

Copies of the above publications and other literature applicable to energy efficiency in industry are available from:

Energy Efficiency Enquiries Bureau
ETSU
Harwell
Oxon OX11 0RA
Tel No: 01235 436747 Fax No: 01235 432923

Information & Guidance Booklet Number 4	- Monitoring and targeting for energy efficiency.
Energy Efficiency Series Guide Number 8	- The Application of monitoring and targeting to energy management.

Copies of the above publications and other literature applicable to energy efficiency are available from:

Department of the Environment
Blackhorse Road
London SE8 5JH

Information is also available through Regional Energy Efficiency Offices (REEOs).

• *Other publications*

CIBSE Lighting Guide: The Industrial Environment. Chartered Institution of Building Services Engineers, London 1984

CIBSE Code for Interior Lighting. Chartered Institution of Building Services Engineers, London 1984.

Copies of these publications are available from:

The Chartered Institution of Building
Services Engineers (CIBSE)
Delta House
222 Balham High Road
London SW12 9BS
Tel No: 0181 675 5211 Fax No: 0181 675 5449

• *The latest news in energy efficiency technology*

'Energy Management' is a free journal issued on behalf of the EEO which contains information on the latest developments in energy efficiency, and details of forthcoming events designed to promote their implementation. It also contains information addresses and contacts for the REEOs.

Copies of 'Energy Management' can be obtained through:

Energy Management Journal
Emap Maclaren House
18 Scarbrook Road
Croydon
Surrey CR9 1QH

Appendix 1

Structure of the Electricity Supply Industry

Most electricity in England and Wales is generated by three companies, namely National Power, PowerGen and Nuclear Electric. All three companies have contracts to supply customers direct, with the surplus output being sold to the 'Electricity Pool'. The Electricity Pool is a financial instrument designed to balance the supply and demand for electricity to ensure the continuity of supply.

Electricity is transmitted in England and Wales by the National Grid Company to the twelve Regional Electricity Companies who then distribute the electricity to their consumers and the customers of the generators who have concluded their agreements. Customers with a Maximum Demand of more than 100kw can enter into an agreement for the supply of electricity with organisations other than their local Regional Electricity Company. The franchise limit, as it is known, is scheduled to be removed totally in April 1998.

In Scotland, a similar situation exists except that the two generating companies, Scottish Hydro and Scottish Power, are responsible for the supply, transmission and distribution of electricity to the majority of customers.

The above situation is slightly complicated by the fact that between England and Scotland a physical interconnection exists which allows power to be transmitted, predominantly from North to South, giving the Scottish generators in particular the ability to supply customers outside their traditional territories.

The terms of the supply contracts between the generators and their customers, who include the Regional Electricity Companies, are obviously confidential, but price messages are given out by the Pool which publishes the costs of supplying electricity in every half hour of each day 365 days a year. For consumers that remain below the franchise limit, whilst it exists, the Regional

Electricity Companies publish tariffs for the supply of electricity that continue to provide price messages to enable their customers to use electricity as economically as possible.

Since privatisation of the Electricity Supply Industry, new generating companies are entering the market with varying sizes of plant. The majority of these new generating plants are gas fired combined cycle facilities with generally higher operating efficiencies than the older, predominantly coal fired, stations which are tending to be retired earlier than originally anticipated. The replacement of generating plant to satisfy the nation's demand for electricity has therefore become a far more commercial decision than hitherto.

Scheduling of all the main generating plant in England and Wales is carried out by the Pool, (operated by the National Grid Company) which has an obligation to ensure that the peak demands are met. This is achieved by ensuring that an adequate level of generating capacity is available from all sources. Capacity is called on to generate in order of station efficiency, known as the 'Merit Order'. Also, short term peak demands are met by calling on the output from smaller gas turbine generators which can be started quickly, although having relatively high operating costs, and by Load Management.

Conversely, low demand at night can cause large 500 or 600 MW generating sets to be shut down or partly loaded; both these operations are inefficient compared with steady load performance and give rise to additional running costs. Clearly demand in this period can minimise these inefficiencies and can therefore be met cheaply. Demand is also affected by the time of the year as well as the time of day. Each of the generators, the National Grid Company and the Regional Electricity Companies' costs, also relate to Maximum Demands and unit consumptions and are reflected in contracts and tariff structures with varying degrees of complexity such that:

- Unit costs are much lower at night with intermediate costs being incurred in the evening and weekends and considerably higher costs on working weekdays, particularly in winter.
- Demand Charges arise in the winter months when consumers' overall requirements reach their highest levels.
- Peaks in demand usually occur late in winter afternoons and this is reflected in some tariff structures where high charges prevail for these periods.

It is through understanding the underlying causes of the various tariffs and applying them to their own electricity use that consumers can seek to minimise costs.

Since privatisation, the Government has established the Office of Electricity Regulation (OFFER) to oversee the whole of the electricity supply industry and to ensure that the rights of customers as well as other interested parties are protected. The Director General of OFFER is empowered to make determinations on contentious issues between suppliers, customers and other interested parties.

Appendix 2

Glossary of Terms Found in Tariff Leaflets

A number of specialised terms are used by the Electricity Supply Industry in their tariffs and contracts. The following are not necessarily strict tariff definitions, nor applicable to all suppliers, but are given as a guide to terms commonly used.

Month:

The period of between four and five weeks between two regular meter readings for quarterly billed supplies (e.g. usually domestic and small non-domestic consumers).

Quarter:

The period of about 13 weeks or three months between two regular meter readings for quarterly billed supplies.

Year:

This can be the period of approximately twelve calendar months between the beginning of April and the end of March or the date of meter readings nearest to those dates or, in some contexts may mean a 'rolling' twelve month period.

Clock Time - Summer Time:

On a normal day, as soon as is reasonably practicable after British Summer Time comes into effect, any clock may be set forward one hour by the REC and similarly after cessation of British Summer Time the clock will be reset. Any times specified in the tariff are Greenwich Mean Time, except that between any setting and re-setting of the time clock, which does not always occur, British Summer Time would apply.

Installed Load:

The sum of the name plate ratings of the electrical apparatus installed on the consumer's premises.

Connected Load:

Part of the installed load of the consumer that may be supplied by the supply authority.

Low Voltage:

Under 1,000 volts, or in some cases a supply where the metering is to the lower voltage side of a transformer located on or near the consumer's premises.

High Voltage:

Over 1,000 volts (typically 11,000 volts known generally as 11 kV).

Standing Charge:

A fixed amount paid by a consumer for a specified period e.g. a year, quarter or month, independent of consumption. The level of the standing charge will vary according to particular considerations such as supply voltage and size and complexity of metering equipment required under the applied tariff.

Availability of Supply:

This term relates to the consumer's physical connection to the supply network, which must be proportioned to meet their maximum power requirement irrespective of the time of day or season in which it occurs. It can sometimes be referred to as **Supply or Service Capacity** or **Declared Capacity**. The capacity is measured in terms of kVA (kilovolt amps) rather than kW (kilowatts) because the latter does not take into account the out of phase components. (See Section 6 - 'Power factor and its correction'). Initially the Service Capacity is likely to take the form of an **Agreed Capacity** (or **Authorised Maximum Demand**). This is agreed in advance and RECs will not normally accept a reduction for some stated period (usually the first five years) following commencement of a new supply, or an increased supply capacity. After this initial period, the charge for **Available Capacity** may be reviewed to reflect either the actual **Maximum Demand** recorded for any month in the previous period (normally twelve months including the month being considered) or any new level of availability which has been agreed between the consumer and the supply authority.

Maximum Demand:

This is the maximum power supplied to a consumer, measured in either kW or kVA. It is usually qualified by reference to the period of time during which this maximum has been recorded.

Annual Maximum Demand:

Demand charges are based on the maximum demand occurring in a period of twelve months.

Seasonal Maximum Demand:

The level of demand charges in such a tariff reflects the season of the year i.e. low in summer and significantly higher in the winter months.

Excess Demand:

This is an arrangement whereby a consumer pays a lower maximum demand charge if this demand occurs at times of low overall system demands. There may be additional metering costs payable under this tariff.

Time of Day Tariffs:

These reflect the variation in energy costs and demands with time, e.g. the domestic "Economy 7" tariff.

Capital Contribution:

The amount paid to the supply undertaking for either the establishment or reinforcement of the service line connecting a consumer to the supply network. This normally applies only where supply costs are very high or customer requirements are exceptional.

Blocked Charges:

An arrangement whereby a series of different tariff rates apply to successive blocks of units supplied during a specified period.

Two Part Tariff:

A tariff comprising two components - normally a standing charge and a unit charge.

Flat Rate Tariff:

A single kWh rate. This may be for electricity supplied for a particular use e.g. lighting.

Restricted Hour Tariffs:

These are where consumption is permitted only during certain periods. Usually taken in combination with other tariffs to form part of a composite arrangement.

Off Peak Tariff:

A special restricted hour tariff where consumption is permitted only outside the hours of peak demand.

Power Factor Clause or Reactive Power Charge:

A price adjustment setting out the additional charges incurred as a result of the consumer's reactive electricity consumption.

Fuel Cost Adjustment Clause/Fuel Index:

An index to take into account changes in the price of fossil fuels consumed by generators. This determines the level of supplement or rebate to be applied to charges.

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